Defining the technology file for GaAs foundry elements

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1. Introduction

The purpose of this work is to provide support using the WaveMaker RF and microwave circuit design software for the external definition of the layout, schematic representation and electrical response of components used in GaAs MMICs.

GaAs MMICs involve the use of multilayer structures that are not supported as standard elements by most of the current microwave circuit simulators. Furthermore, these structures are often not in the standard layout configuration used in the simulators. The rectangular inductor is a good example. Most of the simulators support an inductor. A connection can easily be made to the node located on the outside of the inductor. The other node is located on the inside of the inductor with no means of connection to other external elements. A notable exception to the above is found in the LINMIC+ (TM) software from Jansen Microwaves in which a layout driven design approach has been adopted.

We have developed a macro language for use within the WaveMaker software to enable the GaAs MMIC foundry (and the software user) to construct a technology file for any MMIC process. This file contains the layout and electrical details of the elements used in the MMIC technology. The schematic diagrams of elements used in a particular foundry process can be constructed as individual cells within a cell library in the CALMA GDS II Stream format.

An important aspect of this macro capability is the ability to call up existing models for microstrip elements. The existing models often embody relatively complex code (for example, coupled lines with dispersive effects taken into account). Microstrip transmission lines are placed between multiple dielectric layers, and the electrical characteristics of such lines can often be predicted through the application of a standard microstrip line with modified parameters (for example, through the use of a modified dielectric constant, line length and so on). In this example, the macro file would act as a parameter modifier, with the existing microstrip model being used to calculate the Y parameters.

One thing to bear in mind with this macro facility is the fact that the information is processed in an interpreted manner: in other words, the execution time for any macro model will be longer than the time taken to run through the instructions for an equivalent model that has been compiled into the software. This is the classic drawback associated with the use of interpreted code. The advantage of using such code is that a C compiler is not needed, and the language used is considerably simpler (simple BASIC rather than the full C language).

2. The macro language

We have explored the use of a macro language based on simplified versions of the BASIC and C computer languages, and have concluded that the BASIC computer language is easier to use. The layout definition of the MMIC structures are located in a text file called layout.mac. The electrical description of the MMIC structures are located in a file called sim.mac.

All dimensions are in terms of the WaveMaker data base units, which are in nanometres. All variables are read as double precision real numbers (ie. from 2.2E-308 to 1.7E308). The comma is used to separate variables (and/or mathematical expressions) in the multi-parameter statements. The elements of the macro language are as follows:

standard mathematical operations on and between variables

```
LET variable = mathematical expression

IF function_1 > function_2 GOTO A
   A:

PRINT text_string

FOR L1 = function_1 to function_2
   ...
   NEXT

NODE N1,X1,Y1,ANGLE1
   NODE N2,X2,Y2,ANGLE2
   ...
   LINK_NODE

POINT X1,Y1
   POINT X2,Y2
   ...
   LINK_POLY

YRPARAM row_num,col_num,value

YIPARAM row_num,col_num,value

END
```

The user has access to the following system variables:

present_layer	[the present system layer, 0...63]
present_gran	[present system granularity, 1nm upwards]
present_arcpts	[the present number of arcpts, 3...199]
freq	[the current frequency in Hertz]
sub_0	[the relative diel const of substrate]
sub_1	[substrate thickness in nm]
sub_2	[microstrip metal thickness in nm]
sub_3	[microstrip metal rel (Au) conductivity]
sub_4	[microstrip metal roughness in nm]
sub_5	[loss tangent of substrate]
sub_6	[cover height in nm if specified]

Use of these variables allows the designer to define components with constituent parts on several layers. For example, to define a rectangle on layer 5, we would use the following code:

```
let present_layer = 5
point 0,0
point 100000,100000
link_poly
```

The description of the electrical response of a microwave element may also be defined using this nomenclature. Consider for the moment the description of the ideal lumped resistor as an example:

```
@RES N1 N2 R
IF R = 0 END
G = 1 / R
YRPARAM 1,1,G
YRPARAM 1,2,-G
YRPARAM 2,1,-G
YRPARAM 2,2,G
END
```

Note that the Y parameter array is initialised to zero, and so the zero values for the imaginary components of the parameter array do not have to be defined as such (ie. we do not need to add YIPARAM 1,1,0 for example).

The schematic diagram for any component may be defined in a GDS II Stream cell. The designer may use the graphical editing features of WaveMaker to define the appearance of the schematic diagram.

Several macros may be defined in any of the macro element files. The start of each new element starts off with @component_name, after which one lists the associated parameters. Each macro is terminated with the END or STOP statement. For example, a macro file used to define a triangle and a square (using the relative point RELPT command) would contain the following code:

```
@TRIANGLE W H
RELPT W,0
RELPT -W/2,H
RELPT -W/2,-H
LINK_POLY
END
@SQUARE W H
RELPT W,0
RELPT 0,H
RELPT -W,0
RELPT 0,-H
LINK_POLY
END
```

Once an element has been defined in the macro file, the element may be used as a circuit element in the prediction of the circuit response. Essentially, the designer is provided with a means to define the admittance parameters of any structure and have those parameters appropriately fed into the nodal admittance matrix for subsequent processing.

3. Application of this technology

This technology has been applied to the Philips D05ML GaAs MMIC process as part of a DTI sponsored collaborative exercise between the University of Kent, Philips Microwave and Barnard Microsystems Limited.

4. Conclusion

Most of the commercially available microwave circuit simulation software packages are aimed at the design of circuits to be realised using a variation of the printed circuit board technology. This realisation has prompted the developers of such software to expand the applicability of their software to cater for multi-dielectric GaAs MMICs with their different set of standard structures (for example, the EEsof SMART (TM) libraries).

We have developed the facilities to enable anyone to define the layout, electrical and schematic attributes of the structures available in any particular GaAs MMIC foundry. The importance of this work is that the MMIC designer may now more accurately predict the proper functioning of a GaAs MMIC using the WaveMaker software.

One must emphasise that as with other linear circuit simulators based on the use of analytical expressions, this software does not account for any electromagnetic interaction between closely spaced microwave elements. To account for electromagnetic interaction between microwave elements, and to predict the characteristics of elements at high frequencies, one needs to use a circuit simulator (such as LINMIC+) based on the solution of the electromagnetic fields.